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DIGITAL MAMMOGRAPHY EMPLOYING LAYERED SYNTHETIC MICROSTRUCTURES*

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With conventional film/screen mammography, contrast is an important constraint in the choice of x-ray spectrum employed. Digital mammography frees the system design from constraints of image contrast. If the signal is sufficiently large compared to the image noise, then contrast can be set to whatever is desired at the point of display. The x-ray spectrum should be chosen to maximize signal-to-noise (s/n) per unit of dose administered to the patient. Layered synthetic microstructures (LSMs) can be designed and fabricated to act as bandpass x-ray filters. In this manner the desired x-ray energy region can be selected from a Bremsstrahlung spectrum. In this work we computationally model and compare the s/n and dose performance of a slot-scanning digital mammography system employing an LSM to the performance of the same system using a conventional Mo/Mo spectrum. LSM spectra offer faster, lower dose imaging at all breast thicknesses than conventional Mo/Mo spectra. For an 8 cm breast thickness the LSM spectra can image a calcification in half the time with half the dose of the Mo/Mo design. LSMs coupled with slot scanners offer a practical route to dose-efficient full-field digital mammography.

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The optimal x-ray energy for digital breast imaging depends on breast thickness, composition, the properties of the lesion being imaged, and the characteristics of the detector. In general, this energy increases as breast thickness and glandularity increase. The range of optimal energies is approximately from 15 keV to 25 keV.

Layered synthetic microstructures (LSMs) consist of alternating thin layers of differing materials that have x-ray diffraction properties resembling a synthetic crystal. They can be designed and fabricated to reflect x-rays at specific energies and angles. In the correct configuration, LSMs act as bandpass filters. They have a special compatibility with slot scanning digital mammography designs because the filtered beam has a slot-like shape. Because LSMs are highly effective at suppressing x-rays at energies outside of the bandpass, a W-anode x-ray tube can be operated at relatively high voltage to increase production of Bremsstrahlung x-rays near the optimal energy.

In this work we model the s/n and dose performance of an LSM conditioned system and compare it to predicted performance of an x-ray spectrum representative of that used for conventional film/screen mammography. We also predict the effect of the thickness of CsI:Tl scintillator and breast tissue.

LSM systems offer faster, lower dose imaging at all breast thicknesses than a conventional Mo/Mo spectrum. The advantage in dose efficiency is largest for thick breasts. Table 1 compares an LSM tuned to 21 keV to a Mo/Mo spectrum for a disc shaped calcification of 250 μm diameter and 110 μm thickness in an 8 cm thick breast of 50% glandular tissue and 50% adipose. These results are for a slot scanner with a 1 cm slot width and a 200 μm thick CsI:Tl scintillator. The W-anode tube is taken to be capable of operation at 150 mA while the Mo-anode tube is taken to be capable of operation at 100 mA. We predict that an LSM conditioned beam can achieve the same image s/n in half the time and at one half the dose of a Mo/Mo system.

Table 1: LSM system imaging performance compared to Mo/Mo (s/n=5).

	kVp	conditioning	scan velocity (cm/s)	exposure time (s)	time for 24 cm scan (s)	dose (mRad)
conventional	27	30 μm Mo	1	1.0	24	350
LSM	42	LSM	2	0.5	12	170